IEET 231 Lecture 25
Motor Starters/Controls

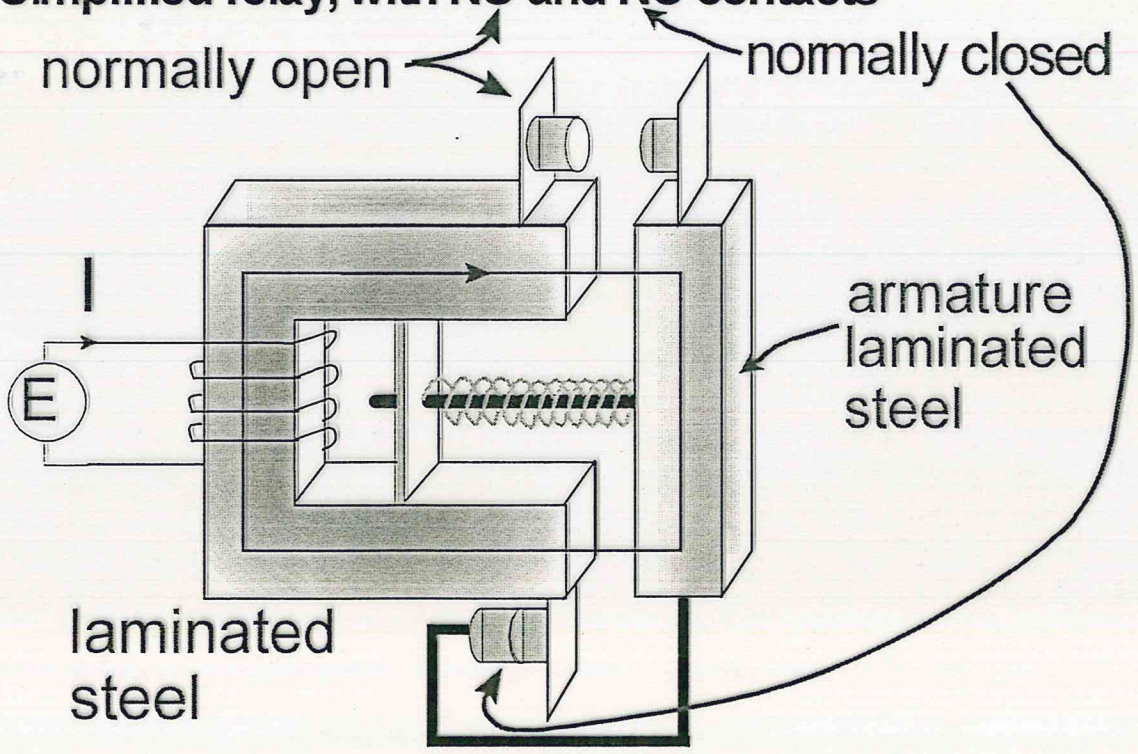
! There are about 1 Billion motors in service in the United States
! Motors account for 67% of the total U.S. electric energy use
! Only 2% of motors are bigger than 5 hp
! That 2% accounts for 70% of the energy used by motors
From the Electric Power Research Institute (EPRI)

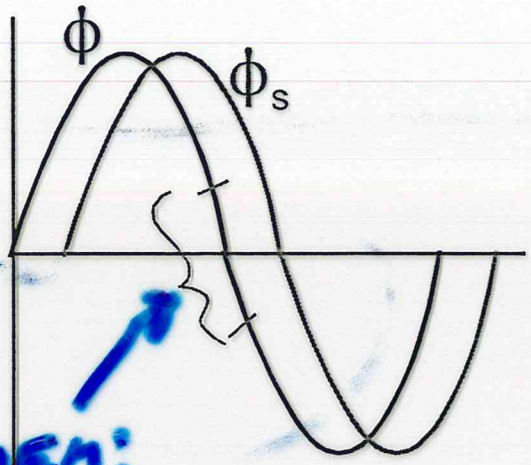
OBJECTIVES

a. Draw a schematic for a basic motor starter, including push button controls and overload protection.

b. Know the symbols for and the principles of operation for normally open and closed relays (with or without time delay), push buttons, and coils.

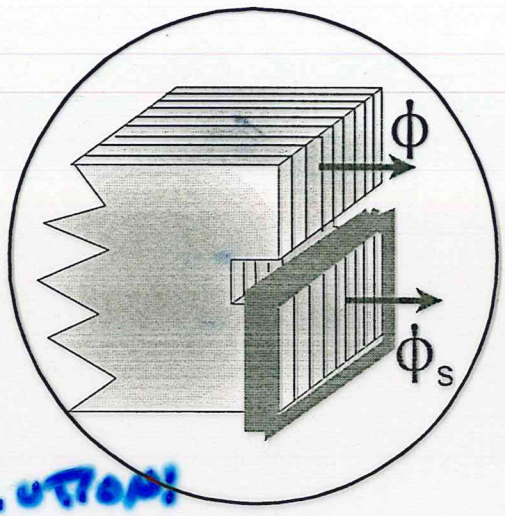
Simplified relay, with NO and NC contacts





PROBLEM:

relay unlatches when flux goes through zero then pulls in again → chatter



SOLUTION:

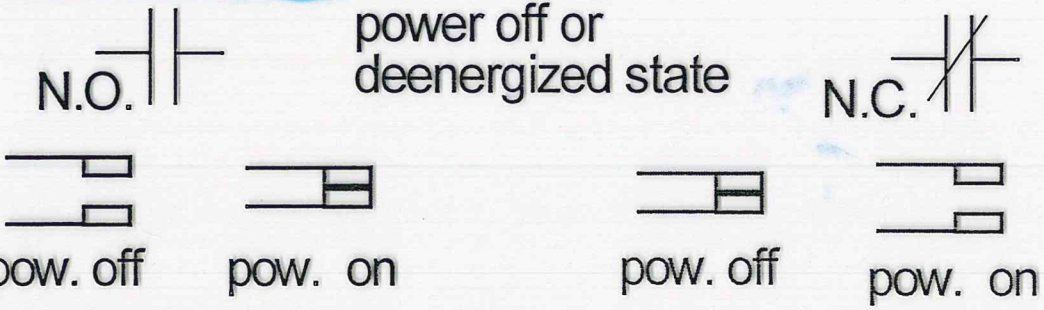
shading pole causes a flux component out of phase with orig. flux → no chatter

Slide 3 of 17

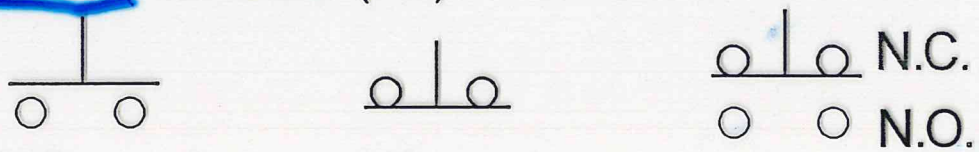
Symbols

General contacts

normal means the power off or deenergized state



Pushbutton contacts (PB)



NO - push to start

NC -push to stop

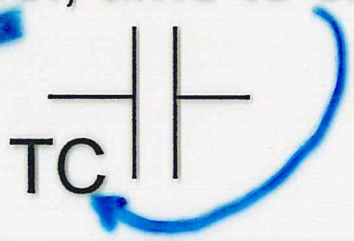
dual contacts single PB

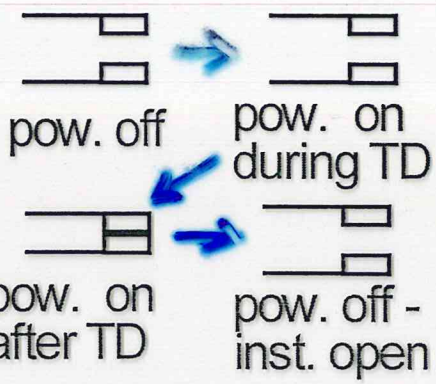
Slide 4 of 17

Time delay contacts

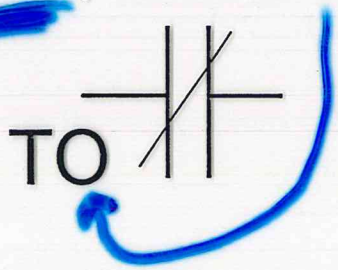
1. delay on energization

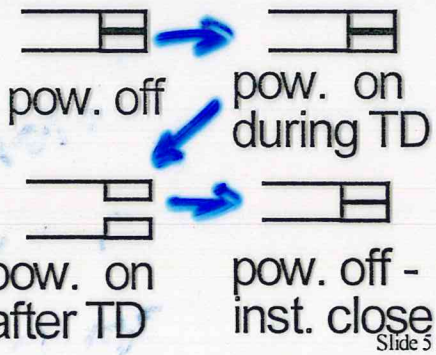
n.o., time to close





n.c., time to open

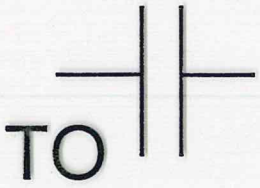


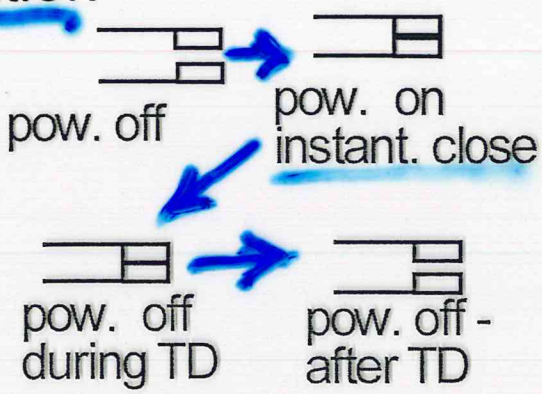


Slide 5 of 17

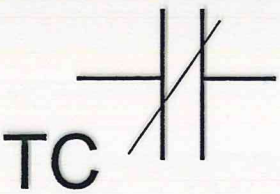
2. delay on de-energization

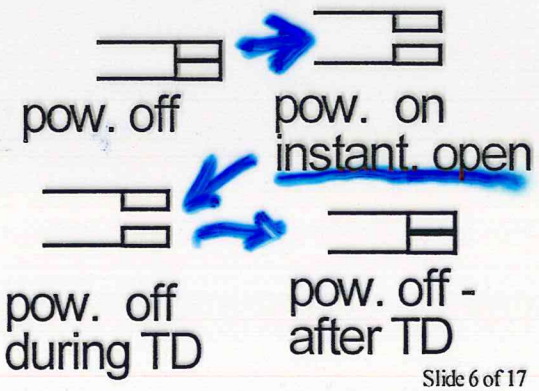
n.o., time to open



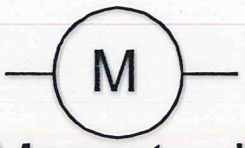


n.c., time to close



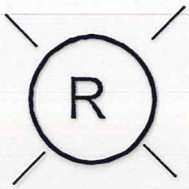


Slide 6 of 17



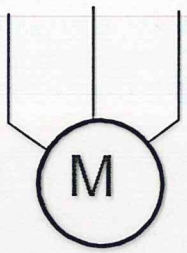
Magnet coil

C - contactor
M - motor starter
H - heater
X - auxiliary

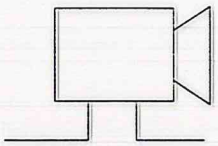


Lamp

G
B



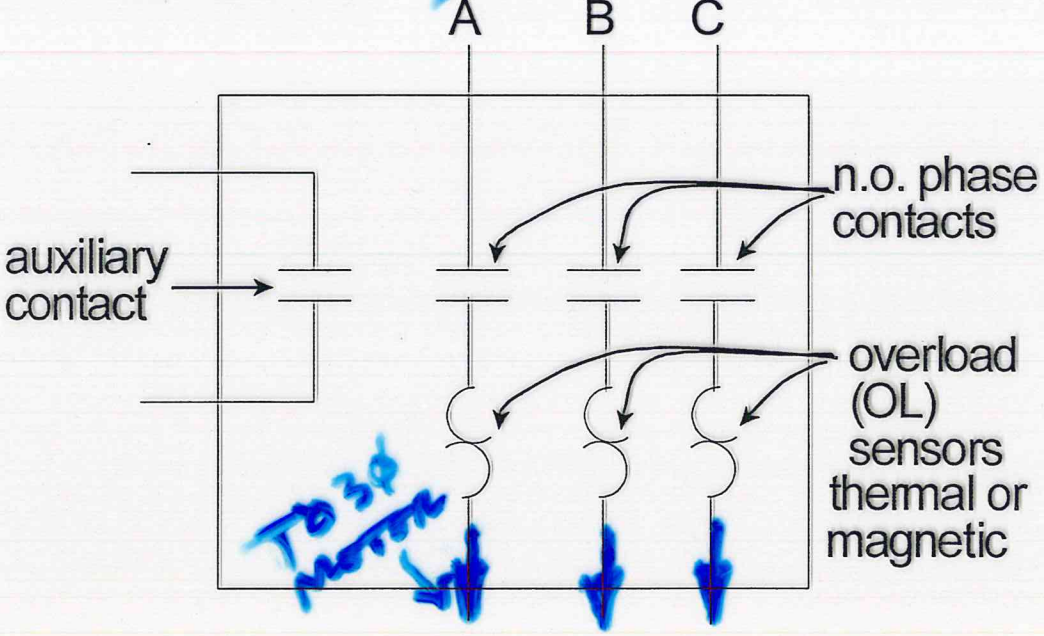
Motor



Horn

INCOMING POWER FOR 3 PHASES

Motor Starters



OL sensors detect abnormal conditions (overload or single phasing) and provide signal to shut down if necessary

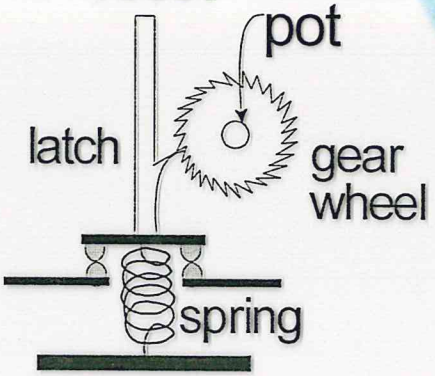
Bimetallic overload

cold

hot

different metals expand at diff. rates when heated so contact bends away when too hot

Melting alloy overload



Types of overload detectors

Thermal can be affected by ambient temp. & are thus less precise, but can be mounted in windings for very accurate indication of overheating

Magnetic detect B field due to currents in winding. Very good for detecting single phasing

Electronic obtain signal from sensor and cause relay to operate

Motor starters and contactors can control large amounts of power with low-voltage, low power devices

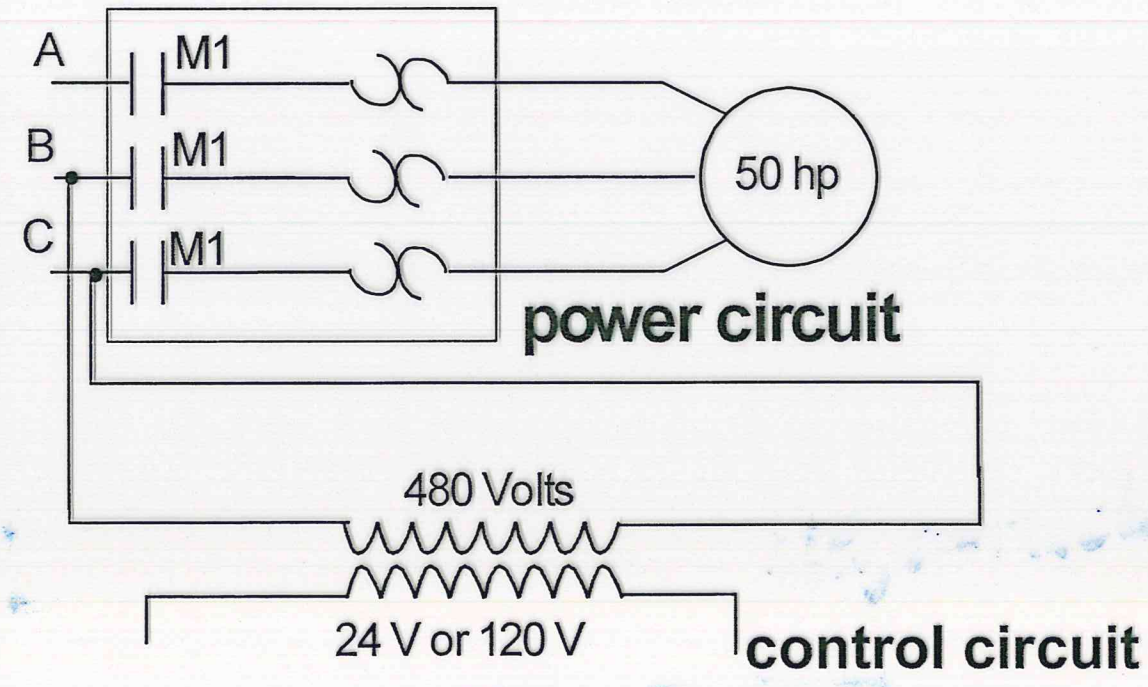
Thus, there are two circuits involved:

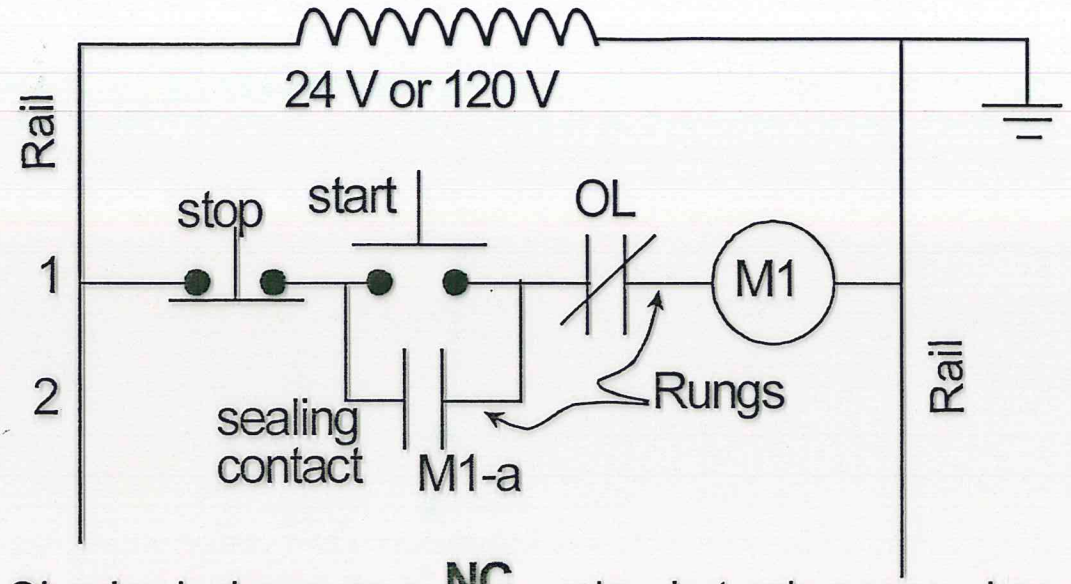
- power circuit
- control circuit

each of which is wired independently

However, their operations are interdependent

Wiring a motor starter





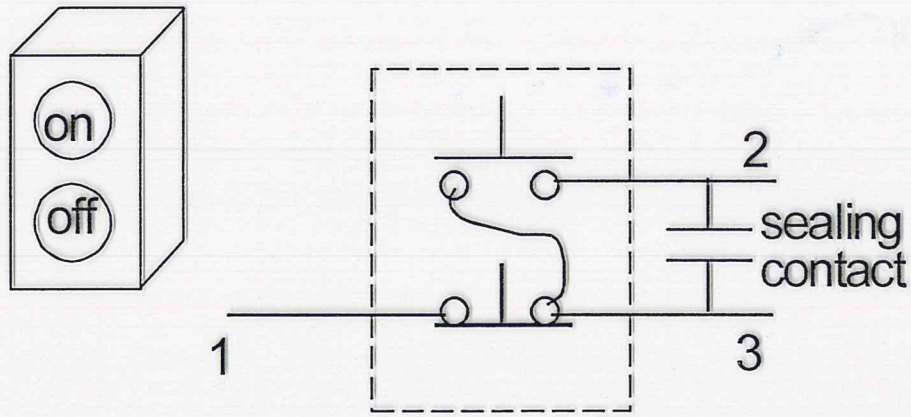
OL relay is drawn as a **NC** relay, but only opens when there is an overload

Sealing (or holding) relay keeps ckt on when start is released

Sides are rails, cross-paths are rungs → **ladder diagram**

Slide 13 of 17

Two and three wire control



3 wire control ≡ undervoltage control (i.e., VOLTAGE ↓ RELAY UNLATCHES)

If relay unlatches, system must be restarted

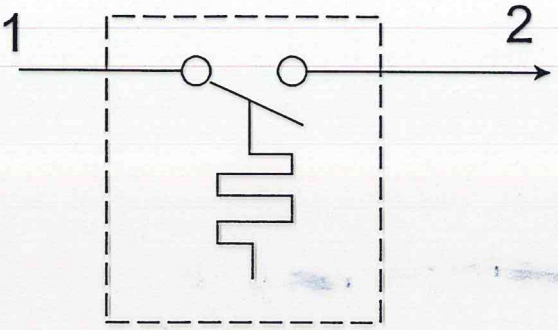
Slide 14 of 17

2 wire control:

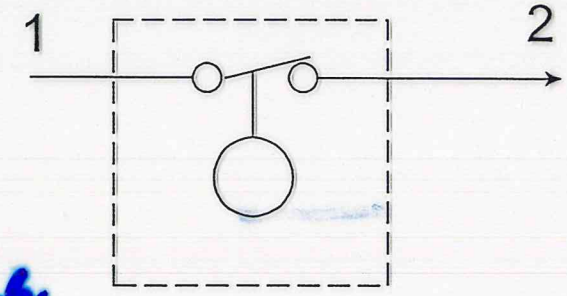
undervoltage release

if voltage drops, coil can't hold relay closed and system shuts down

returns to service whenever voltage is restored

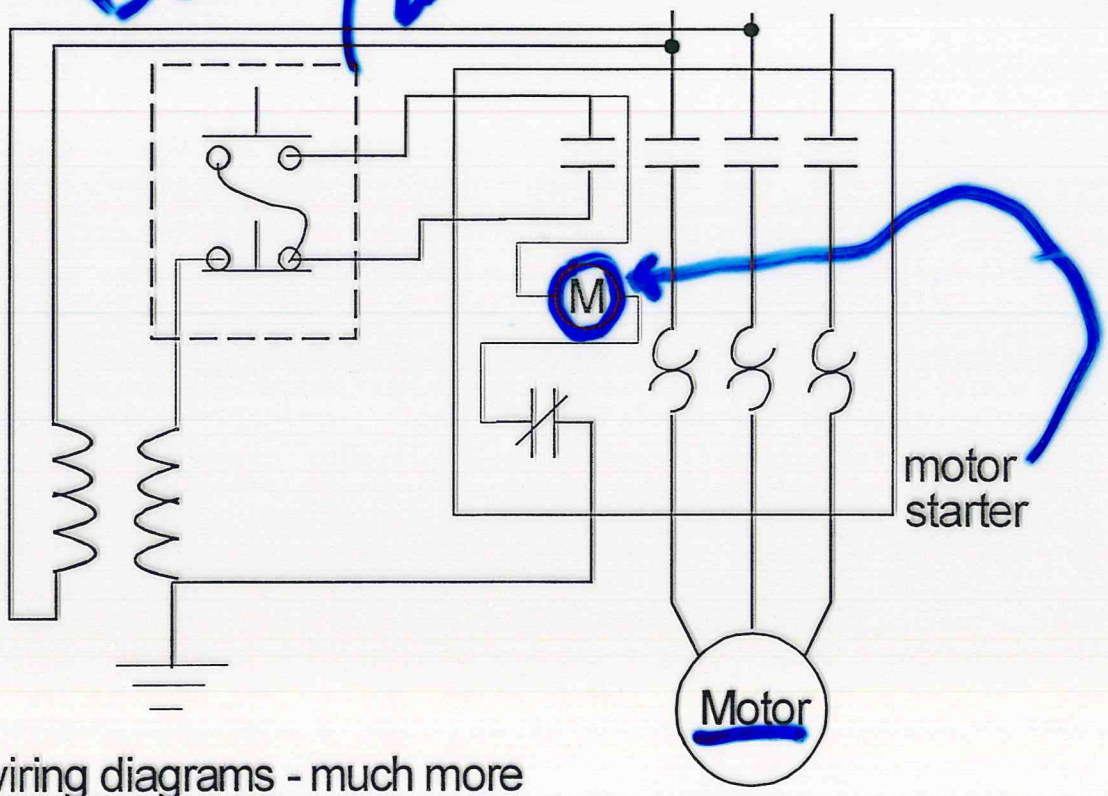


thermostat

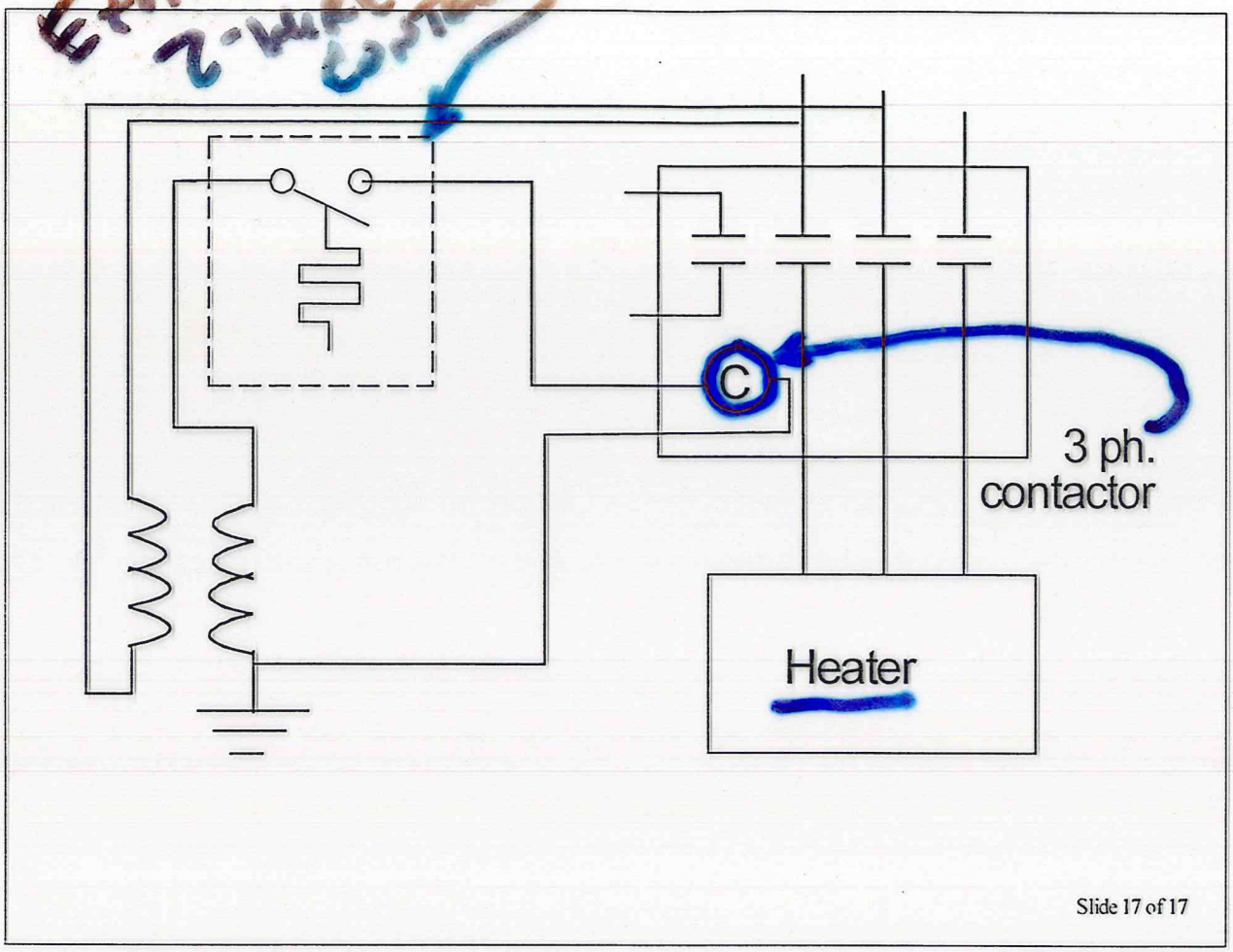


float switch

EXAMPLE 3-WIRE CONTROL



wiring diagrams - much more difficult to work from


C
3 ph.
contactor
Heater
Slide 17 of 17

EET 231Lecture 26
Ladder diagram development

Objectives:

a. Be able to construct a ladder diagram for a control circuit given the operational requirements for the system.

b. Given a ladder diagram:

Identify the purpose of each component
Identify what each component is
Properly label the rung numbers to the left of left rail
Properly label control functions to the right of the right rail
Describe the operation of the control circuit

Steps for developing a ladder diagram

Process is as much an art as science, however, certain steps can be followed:

1. Consider system, make sketch of all components
2. List out the desired operating sequence - table, sentences, or state-diagram
3. Draw ladder diagram to achieve desired operation
4. Verify operation of ladder diagram
   manually run through operation
   list each device when operated
   cross off each device when deactivated
   End of cycle → **everything should be crossed off**

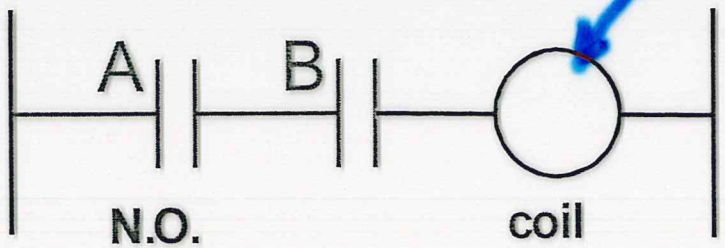
Some similarities to digital circuit design

- AND function

two or more things must happen

"A and B"

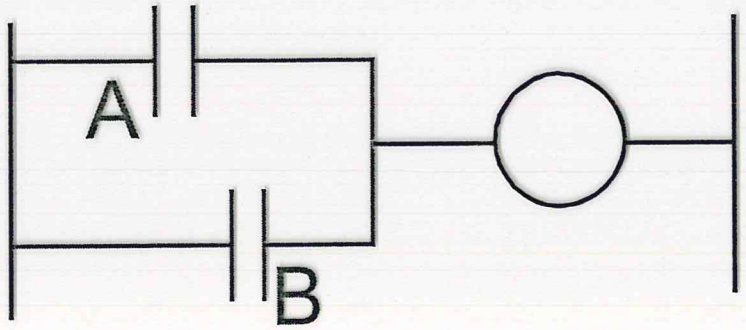
TO ENERGIZE THIS RELAY (COIL)



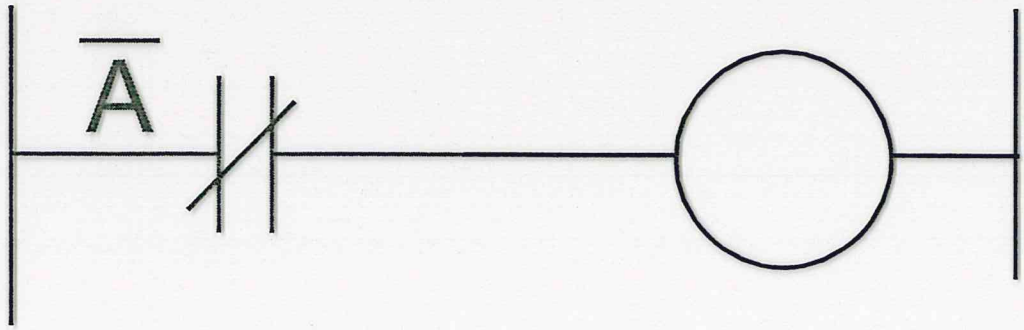
- OR function

one or both things must happen

"A or B"

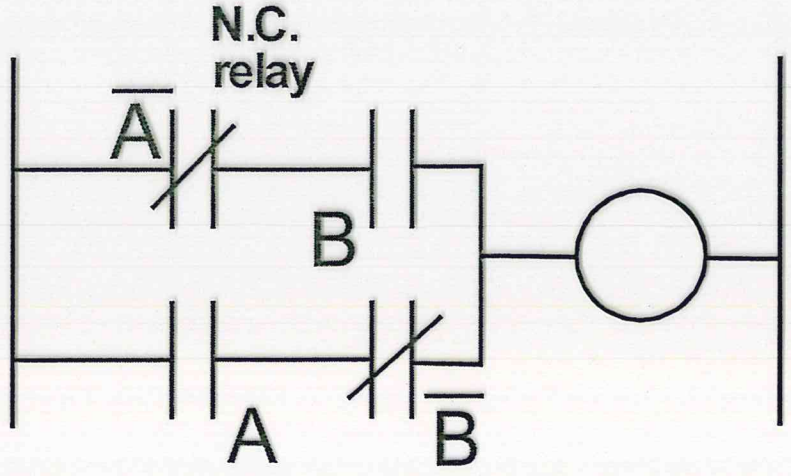


- NOT



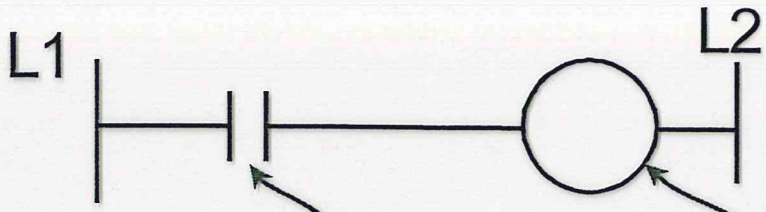
- XOR (exclusive or)

($\overline{A}$ and B) or (A and $\overline{B}$)



Conventions for ladder diagrams

- power source may not be shown

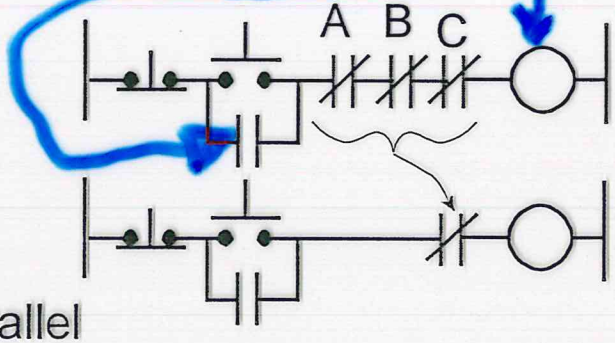


- switches and relays are inputs and go on the left side of the rungs

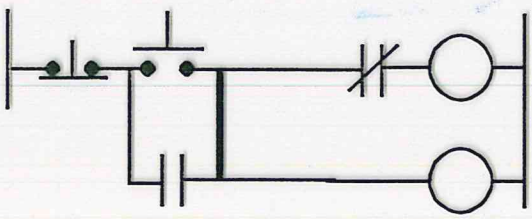
- lamps, coils, horns, etc are outputs and go on the right side of the rungs

Conventions for ladder diagrams

- all OL relays may be shown as one



- one input can control multiple outputs in parallel



- rungs are consecutively numbered from top to bottom to the left of the left rung

Conventions for ladder diagrams

- rungs are consecutively numbered from top to bottom to the left of the left rung

- sequence of operation is generally from top to bottom but some skipping around may occur

- any given relay, contactor, or motor starter may have multiple contacts which can be used anywhere in the diagram

- rung numbers of controlled contacts are placed to the right of the right rung. Underlined numbers indicate a normally closed contact

- contacts are labeled with the same alphanumeric designation as the coil that controls them

Example

Design controls for a heater and blower device

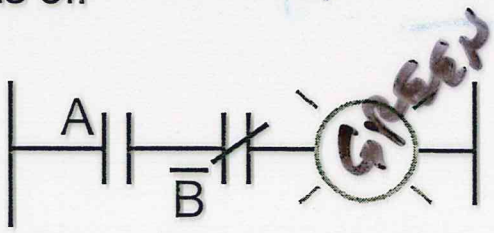
Specifications:

- circuit should have manual on-off control
  - ∴ requires a start/stop pushbutton set
- blower shouldn't come on until heater is warm
  - ∴ need thermostat or time delay relay

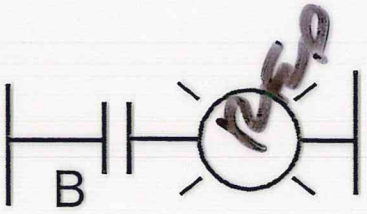
Example (cont)

Specifications:

- green light on whenever start switch is on (A) to the control circuit and heater is off ($\overline{B}$)



- red light on when the heater is on (B)



Example (cont)

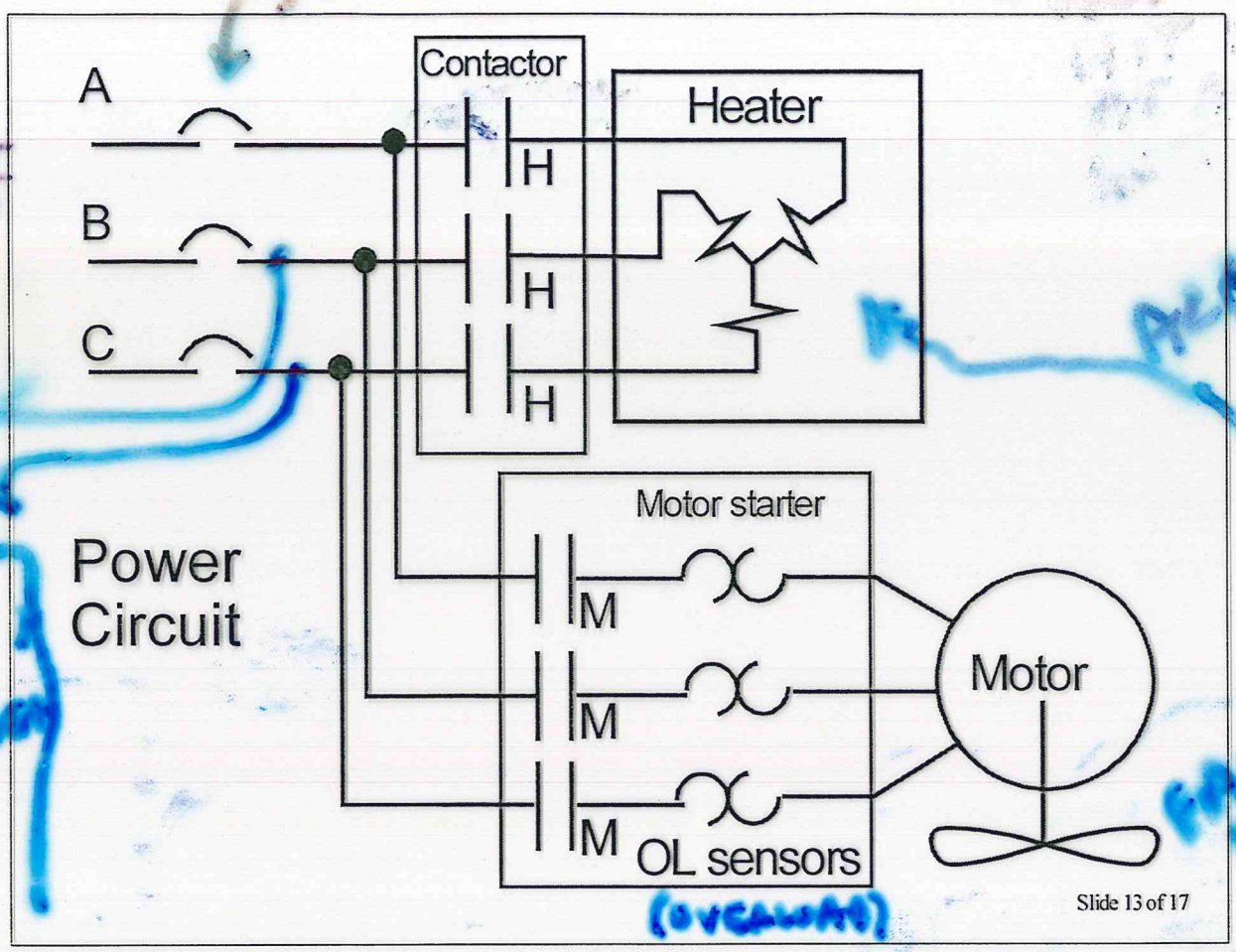
Specifications:

- heater/blower turns off when desired temperature is reached

∴ need thermostat

- once turned on, device should cycle on and off as temperature changes

∴ control power stays on when thermostat shuts off heater and blower



Slide 13 of 17

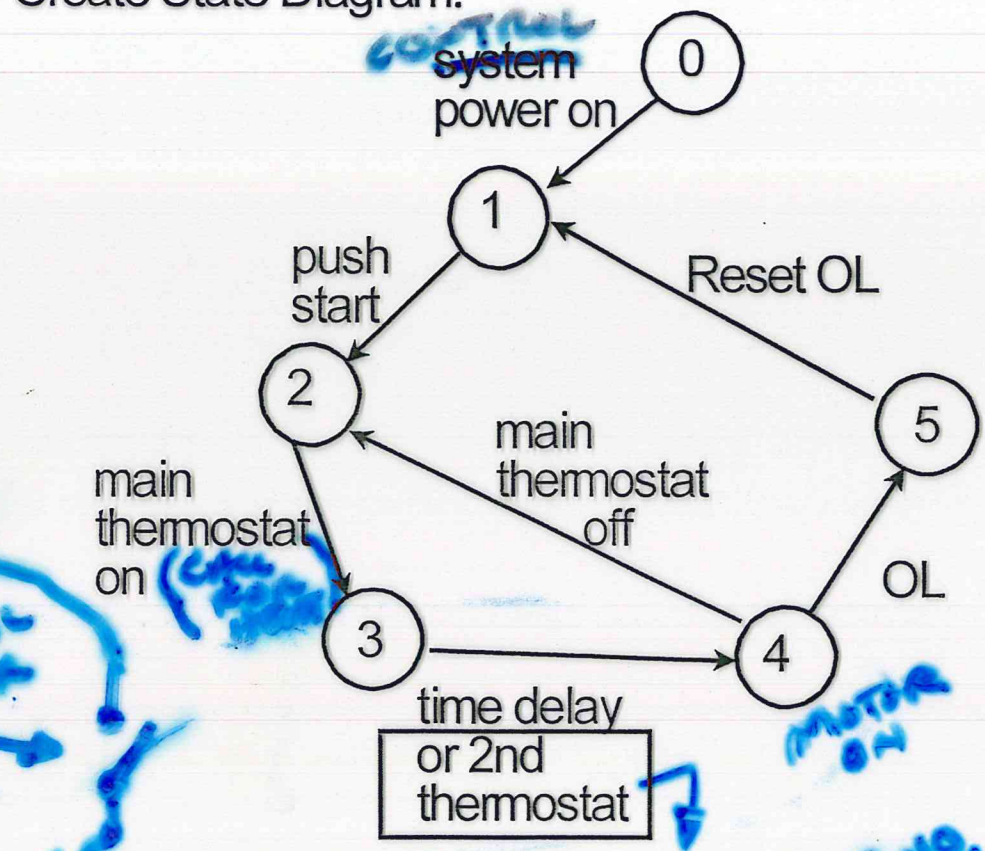
State #	State Condition
0	No power available, system is dead
1	System is completely off, left rail of ladder diagram is hot
2	Control power on, thermostat off, green on
3	Thermostat closed, heater on, green off, red on
4	Same as 3, but motor is on
5	Everything shut down due to motor OL OL tripped

NOTE:

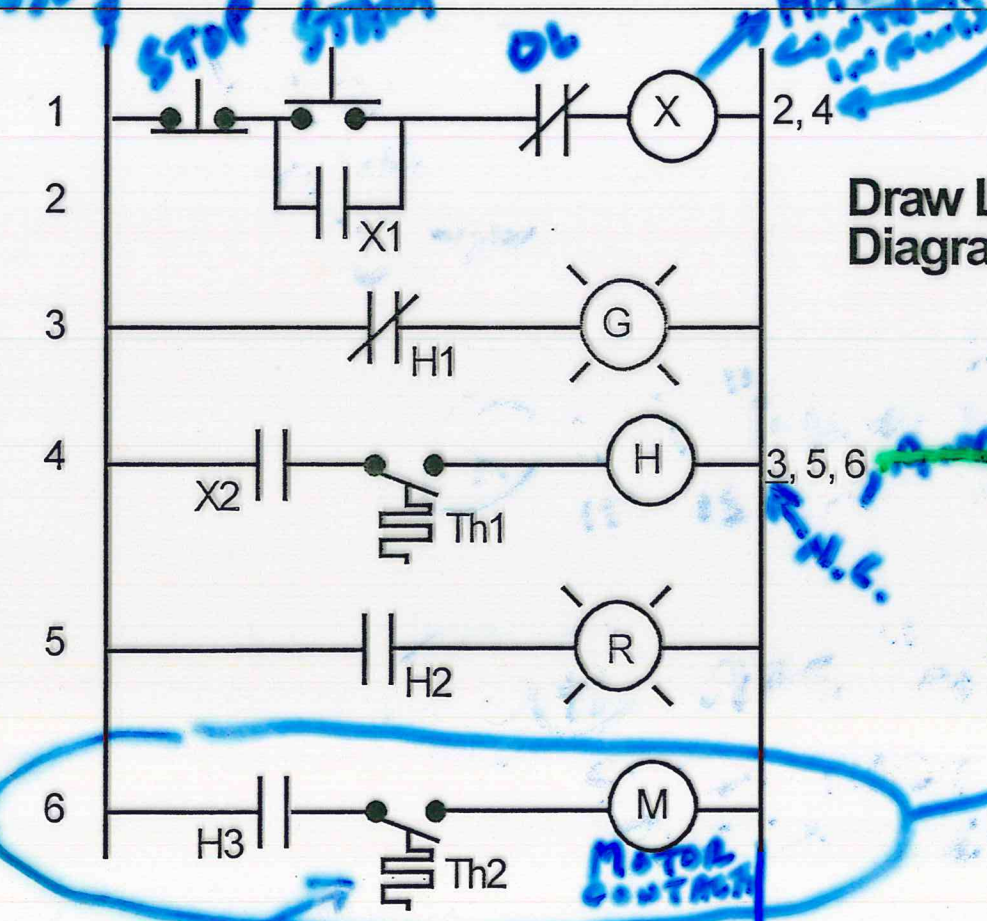
1. from any state a power failure goes back to st. zero
2. from any state>1, push stop to return to state 1
3. from state 5, reset OL to return to state 1

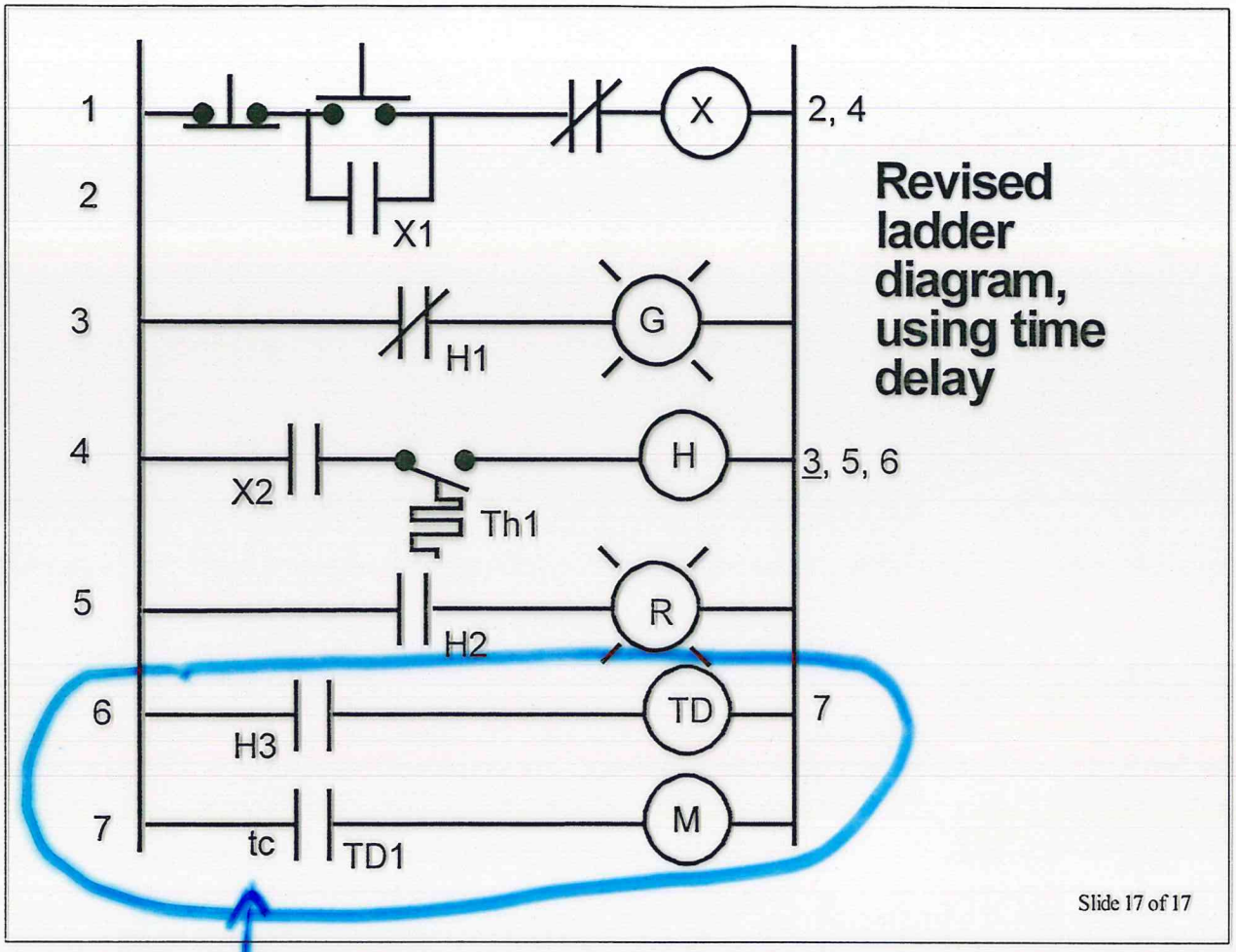
Slide 14 of 17

Create State Diagram:



Draw Ladder Diagram:





N.D.
TIME TO CLOSE

(X) IS A "RELAY" SINCE IT IS A CONTROL DEVICE

(M), (H) ARE "CONTACTORS" SINCE THEY ARE POWER DEVICES (AND NOT CONTROL DEVICES)